SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*THE IMPERIAL PHYSICO-TECHNICAL INSTITUTION IN CHARLOTTENBURG.**

I. HISTORICAL.

THROUGH the courtesy of Professor Kohlrausch, President of the Reichsanstalt, and the Curatorium or governing body of the institution, the writer was accorded the privilege of working in the Physikalisch-Technische Reichsanstalt as a scientific guest during the last few months of 1899. An unusual opportunity was thus afforded of learning rather intimately the methods employed and the results accomplished in this famous institution for the conduct of physical research, the supply of standards and the verification of instruments of precision for scientific and technical purposes.

It is well-known that the Reichsanstalt is situated in Charlottenburg, a suburb of Berlin just beyond the renowned Thiergarten. The buildings occupy an entire square, the larger part of which, valued at 500,000 Marks, was the gift of Dr. Werner Siemens. In making this gift, which was offered in land or money at the option of the government, Dr. Siemens declared that he had in mind only the object of serving his fatherland and of demonstrating his love for science, to which he avowed himself entirely indebted for his rise in life.

* A paper presented at the 146th meeting of the American Institute of Electrical Engineers, New York, September 26, 1900.

The gift was made as a stimulus to the government to establish an institution for physical research. The kind of institution desired had been amply described in suitable memorials prepared by himself, Professor von Helmholtz and others of scarcely less distinction. The first memorial bears the date of June 16, 1883. It relates to 'The Founding of an Institution for the Experimental Promotion of Exact Natural Philosophy and the Technical Arts of Precision.' It points out the need of such an institution, details the benefit likely to accrue from it, lays great stress on the intimate relation existing between scientific investigations and their application in the useful arts, and sets forth somewhat in detail a plan of organization. The memorialists had in mind at that time a 'Physico-Mechanical Institution,' but in the memorial of the following year (March 20, 1884) the title was changed to the one which the institution now bears—'Physikalisch-Technische Reichsanstalt.' From this second memorial it is learned that the first steps toward the furtherance of exact science and technical precision, in an institution to be founded and maintained by the State, were taken as early as 1872. This movement had the support of the crown-prince, the late Emperor Frederick, and the matter was taken in hand by Count von Moltke as chairman of the Central Bureau for Metrology in Prussia. He called together a commission near the end of the year 1873, and in the following January this commission reported a series of propositions for the improvement of the scientific, mechanic arts, and of instruments of precision. These propositions formed the foundation for a memorial on the same subject to the Chamber of Delegates of the Prussian Government in 1876. The result was that appropriate rooms were set aside in the new building of the Technical High School in Charlottenburg for the organization of an institution for the cultivation of the arts of precision.

The general plan of the Reichsanstalt was adopted in 1887, and an appropriation of 868,254 Marks was made and spread over the budget for three years. The main building for the first or scientific division was completed in 1893. The second or technical division was housed in a portion of the Technical High School till the buildings for this division were completed in 1897. All departments of activity of the Reichsanstalt are now accommodated on the square facing on March Strasse in Charlottenburg. They include the division for pure scientific research, mechanical measurements of precision, electrical measurements and instruments, the measurement of large direct and alternating currents and electromotive forces, the optical department, the department of thermometry, the department of pyrometry and the department of chemistry. To these as auxiliaries should be added the power plant and the workshop.

II. ORGANIZATION.

The two divisions into which the Reichsanstalt is divided correspond to the two paramount objects which the founders had in view, viz., research in pure science, and the cultivation of precision in the technical applications of science. The same idea is embodied in the very name of the institution—the Imperial Physico-Technical Institution. If the sole purpose of the Anstalt had been the promotion of improvement in the mechanic arts, in engineering and in instruments of precision, the first or scientific division would still have been essential to secure the ends sought. All the applications of science rest on the foundation of pure scientific discovery. The creation of new and improved methods and instruments for physical measurements requires the most exhaustive and painstaking investigations as a preliminary to a steady and

confident advance. The practical value of research in pure science is no longer in question. The wise founders of the Reichsanstalt made no mistake in coupling an institution for the promotion of technical precision with one for the prosecution of research in physical science.

The governing body or Curatorium of the Reichsanstalt is appointed by the Emperor. At its head is Herr Weymann, Imperial Privy Counsellor. The function of the Curatorium is the appointment of the officials and the general management of the institution. The chief officer of the Reichsanstalt is the President, and the most distinguished physicist of the realm is sought for this position. Helmholtz was taken from the University in Berlin to become the first incumbent of the office; after his death in 1893, his successor as professor of physics in the University, Professor F. Kohlrausch, became his successor as President of the Reichsanstalt.

The President, who is at the same time director of the first division, is held responsible for the successful work of the Reichsanstalt. All other officials are therefore subordinate to him. In his absence the duties of his office devolve upon the Director of the technical division. Subordinate to the director of this second division are the professors, associates, and assistants of various grades. A professor in charge of a department has the direction of all those employed in it, including a skilled departmental mechanician.

The specific duties of the President may be briefly enumerated. He must lay before the Curatorium at its annual meeting the following:

1. A report on the work executed in both divisions.

2. The plan of work for the undertakings to be carried out the ensuing year.

3. Propositions relative to the money to be expended for scientific and technical work; also for salaries and remunerations.

4. Propositions relative to the rank of permanent associates and assistants; also relative to the bestowal of places to work in the Reichsanstalt as scientific guests.

He takes a vote on the propositions in 3 and 4, and reports the conclusions of the Curatorium to the government for approval. It is also the duty of the President to sign vouchers for all payments, and he is held responsible for the proper expenditure of the money appropriated for the maintenance of the institution.

The different functions of the two divisions composing the institution are defined in rather broad terms. It is the duty of the first division to carry out physical investigations requiring more uninterrupted time on the part of the observer, and better accessories in the way of instruments and local appliances, than private individuals and laboratories of institutions for teaching as a rule can offer. These investigations shall be carried out partly by officers of the Anstalt and partly, under their oversight, by scientific guests and voluntary workers. By scientific guests in general are meant the holders of scientific positions in the German Empire who wish to prosecute scientific researches, the plan of which they have submitted, and for which they have not at home the necessary appliances. They must be recommended by the State in which they reside and must be accepted by the Curatorium.

Young men may be accepted as voluntary workers who have proved their ability by scientific publications. They will undertake researches which have been determined upon by the Curatorium or the Director; or they may investigate subjects which they themselves suggest, and which appear to the Director to be practicable and worthy of execution. The scientific results obtained must be published only at the dis-

cretion of the authorities of the institution, who reserve also the right to publish them in the researches of the Reichsanstalt. Provision is made that voluntary workers shall not use the institution for private ends nor to obtain patents.

The second division of the Reichsanstalt is placed under a Director, who is subject to the higher authority of the President. Such a Director was considered necessary on account of the special work of this division, as well as because of the intimate relations into which it is brought with many persons engaged in industrial pursuits. He should therefore not only be a scientific man, but should at the same time have some technical knowledge of the applications of science. Under the Director are placed the permanent heads of the subdivisions of the technical department, one having the oversight of thermometry, one of optics, two of electricity, and one of mechanical measurements of precision. Along with these, and of the same rank and compensation, is the director of the workshop. Under him at present are eight mechanics, and the shop is provided with the finest tools for the execution of the most exact work required by the institution. For example, it has a circular dividing engine that cost $2,500. The founders of the Reichsanstalt foresaw the necessity of such mechanical aids for the furtherance of the exact work to be undertaken. They wisely concluded that such special constructions and new types of instruments as they might require from time to time could be more conveniently and more cheaply built in their own shop than by private instrument makers.

III. COST AND MAINTENANCE.

The following are the official accounts of expenditures for the grounds, buildings, furniture and instruments for the two divisions, to which are added the yearly expenses:

DIVISION I.

1. Acquisition of ground, the gift of Dr. Werner Siemens	500,000 M.	
2. For erection of buildings:		
a. Main Building	387,000 "	
b. Machinery Building	50,000 "	
c. Administra'n Building	100,000 "	
d. President's House	99,254 "	
e. Grading, Paving, etc.	10,472 "	
f. Paving Half of Street	30,274 "	
g. Building for Battery	8,500 "	
3. Fittings and Furniture	58,000 "	
4. Equipment of Machinery and Instruments	82,310 "	1,325,810 M.

DIVISION II.

1. Acquisition of Ground	373,106 M.	
2. Erection of Buildings:		
a. Main Building	922,000 "	
b. Laboratory Building	218,000 "	
c. Machinery Building	180,000 "	
d. Dwelling for Offic'ls	140,000 "	
e. Additional Improvements	348,000 "	
3. Fittings and Furniture	108,300 "	
4. Equipment of Machinery and Instruments	471,390 "	
	2,760,796 M.	
Less reduction for 1895–96	47,500 "	2,713,296 M.
Divisions I and II together.		4,039,106 M.

The annual expenditures for 1899 were as follows:

1. Expenditures for Salaries and Laborers	206,604 M.
2. Miscellaneous Articles, Experimental Work and Care of Buildings	127,000 "
Total	333,604 M.

The receipts for calibrating instruments, testing materials, verifying standards and the like now amount to about 40,000 M. annually. This sum should be deducted from the yearly expenditures, leaving a net sum of about 300,000 M.

In round numbers the Reichsanstalt has cost $1,000,000, and the annual appropriation for its maintenance is $75,000.

IV. RESULTS.

A very pertinent inquiry is, what are the results of all this expenditure? Might not more good be accomplished by State aid to some existing technical school or university? The results attained must be set by the side of the objects which the founders of the institution had in view in order to ascertain whether the sequel has justified their predictions. In the memorials to which reference has already been made, Professor von Helmholtz and Dr. Werner Siemens pointed out the advantages likely to accrue to Germany from the maintenance of an imperial institution for research, which should at the same time assume the cognate function of fixing and certifying standards of mechanical and physical measurements. Attention was drawn to the fact that other countries, notably England, had enjoyed great renown in science because of the brilliant researches and discoveries of some of her scientific men, who had the good fortune to be possessed of leisure and large private means, and the scientific spirit to devote them to investigations demanding both as a *sine qua non*.

These conditions the memorialists declared were lacking in the fatherland. Her scholars who had the enthusiasm and the capacity for exact scientific investigation possessed neither the private fortune to devote to it, nor the uninterrupted time for the execution of the work. They were to be found among the men engaged in teaching, but their professional duties absorbed their time to such an extent that only an inadequate residue remained; and even this little was divided into fractions too small to admit of the sustained and continuous attention which any important investigation demands.

It was further pointed out that if the government would supply the conditions favorable to scientific discovery, the men could be found whose work would reflect great credit on the State, while the interaction between pure science and its applications to arts and manufactures would put Germany in the forefront of scientific renown and of the intelligent application of science to useful purposes.

It was further urged by von Helmholtz that the brilliant investigations of Regnault and other French physicists many years ago should now be repeated with the superior methods and instrumental appliances available at the present time. These investigations drew the attention of the scientific world to France and made it the focus of scientific interest. Her instrument makers, even up to the present, have reaped a rich reward in foreign orders for instruments made eminently desirable and almost indispensable by these distinguished French investigators.

Other problems, too, needed solution, problems forced to the front by modern requirements and discoveries. The applications of electricity, for example, present new questions for science to answer, while the interests of the consumer at the same time call for some form of control by the State of the instruments employed in fulfilling contracts. The very units in which such measurements are made need to be authoritatively settled—a task demanding the highest manipulative skill in experiment and the most refined appliances which experience can suggest and money purchase.

The German government admitted the force of these considerations and made splendid provision, for both pure science and its technical applications, by founding the Imperial Institution at Charlottenburg. The results have already justified in a remarkable manner all the expenditure of labor and money. The renown in exact scientific measurements formerly possessed by France and England has now been largely transferred to Germany. Formerly

scientific workers in the United States looked to England for exact standards, especially in the department of electricity. Now they go to Germany. So completely has the work of the Reichsanstalt justified the expectations of its founders, and so substantial are the products of this already famous institution that other European nations are following Germany's example. Great Britain has already made an initial appropriation for a National Physical Laboratory to be organized on a plan similar to that of her Teutonic neighbor. Mr. R. T. Glazebrook, who has long served as secretary of the electrical standards committee of the British Association for the Advancement of Science, has been appointed Director and has entered on his duties. The new institution will absorb the old Kew Observatory, and other buildings will be added at once for the extension of the functions of this Observatory so as to include the larger enterprise contemplated in the establishment of the new National Laboratory.

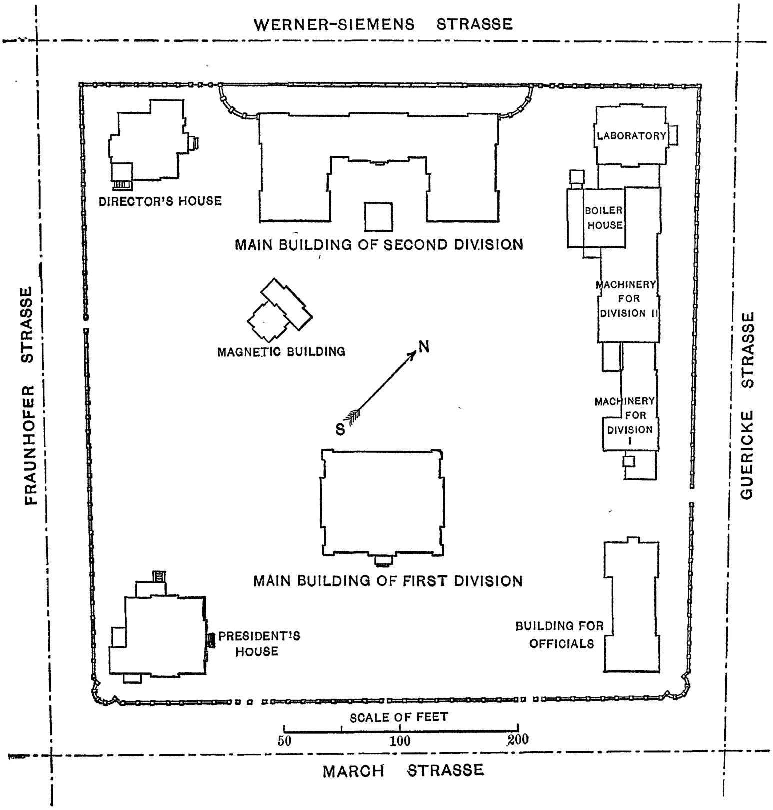

FIG. 1.—General Plan of Ground and Buildings.

Russia also has a number of large and well equipped laboratories in connection with her Central Bureau of Weights and Measures. One of these is devoted to the verification of instruments for electrical measurement. It employs fourteen men and the budget is about $45,000 per annum.

France is moving in the same direction. The great service of France in fixing standards of length and mass has long been freely recognized by the civilized world. But her national bureau for this purpose is now considered to be too limited in scope to solve

the new problems presented. Quite recently a committee of learned men from Paris, under the leadership of Minister Bourgeoise, visited Charlottenburg for the purpose of examining into the working of the renowned institution located there. Professor Violle, one of the most illustrious physicists of the French capital, accompanied the committee. What better evidence of the success of Germany's great institution can be demanded than the consensus of favorable opinion among those best qualified to judge that its fruits are already of the highest order of merit, and its imitation by other European nations—the sincerest form of flattery.

It would not be just to form an estimate of the success of the Reichsanstalt without taking into account its scientific publications. These are numerous and of great value. Most of the reports of work done are made public with official sanction in various scientific and technical journals. During the past year thirty such papers have been published. The detailed accounts, however, of the most important undertakings thus far completed are contained in three quarto volumes of investigations. Among those contained in the first two volumes may be mentioned papers pertaining to thermometry and to units of electrical resistance.

The investigations in thermometry comprise such topics as the influence of the glass on the indications of the mercurial thermometer, division of the thermometer and determination of the errors of division, determination of the coefficient of outer and inner pressure, determination of the mean apparent coefficient of expansion of mercury between 0°C. and 100°C. in Jena glass, and investigations relating to the comparison of mercurial thermometers.

Four papers of exceptional value relate to normal standards of electrical resistance. They are, the probable value of the ohm according to measurements made up to the present time, the determination of the caliber correction for electrical resistance tubes, the normal mercury standard ohm and the normal wire standard ohm of the Reichsanstalt. When one recalls that the ohm as a practical unit of measurement is defined in terms of the resistance of a specified column or thread of mercury, it will readily be seen that the work done at Charlottenburg in this particular field is fundamental in character and of the most universal importance.

In passing it is worthy of remark that all the standard resistances designed and constructed at the Reichsanstalt are carefully compared with the mercurial standards early in each year. This custom is in accordance with the action taken by the electrical standards committee of the British Association at Edinburgh in 1892, when the mercurial standard was definitely adopted. At this meeting of the committee, representatives of American, French and German physicists (including von Helmholtz) were invited to sit as members. The methods employed in these comparisons and the forms of the standards are original with the Reichsanstalt. The new forms and methods admit of a combined accuracy and convenience not previously attained.

In addition to the work done in electrical resistance, the investigation of the silver voltameter and the electromotive force of standard Clark and Weston cells has been highly productive of useful results for the other two fundamental electrical measurements. Much remains to be done in this latter direction, for the electromotive force assigned to the Clark and Weston cell, even in the latest report of the Reichsanstalt, is derived from measurements by the silver voltameter, while the electrochemical equivalent of silver is in doubt to a greater extent than the electromotive force of the Clark cell.

Perhaps the best indication of the valuable work of the Reichsanstalt is to be found in the annual 'Thätigkeitsbericht.' This report of the year's activity is published in the 'Zeitschrift für Instrumentenkunde,' and the reprint for 1899 forms a pamphlet of twenty-five large, closely printed pages. The following abstract will

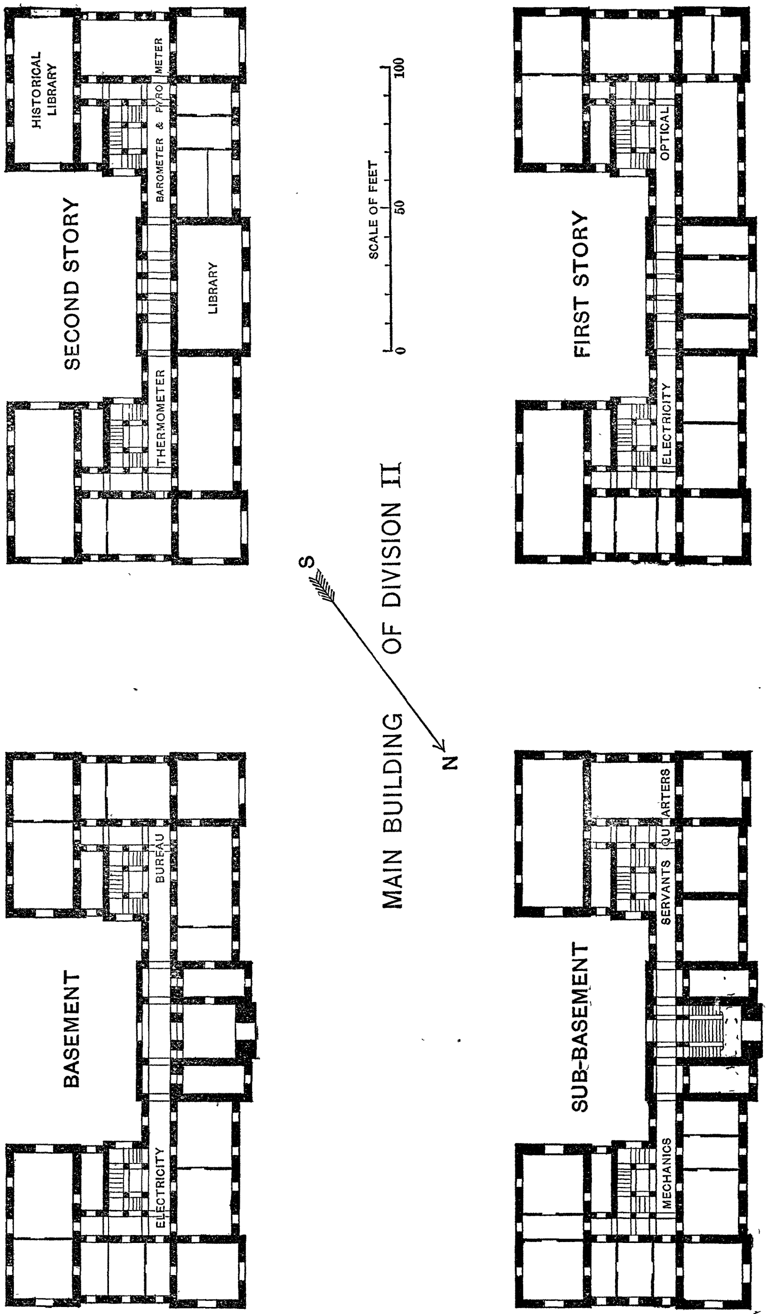

FIG. 2.—Floor Plans of Main Building. Division II.

convey some impression, though an imperfect one, of the extent of the work accomplished :

FIRST (PHYSICAL) DIVISION.

I. *Work in Heat.*—Determination of the density of water between 0° C. and 40° C.

Determination of the pressure of water vapor at low temperatures.

Determination of the pressure of water vapor near 50° C.

Investigations of thermometers for temperatures between 100° and 200° C.

Investigation of the nitrogen thermometer with a platinumiridium bulb for very high temperatures.

Investigation of thermometers for low temperatures.

Determination of the thermal and electrical conductivity of pure metals. (These determinations are to be extended down to the temperature of liquid air and up to 1,000° C.)

Investigations with the Fizeau-Abbe dilatometer.

Investigation of the transmission of heat through metal plates.

II. *Work in Electricity.*—Comparison of the normal wire resistances of Divisions I and II.

Determination of the capacity of an air condenser.

Comparison of the standard cells of Divisions I and II.

Determination of the conductance of water solutions with a higher degree of accuracy than has been attained hitherto, especially with dilute solutions.

III. *Work in Light.*—Investigation with electrically heated black bodies.

Proof of Stefan's law between 90° and 1,700° absolute temperature.

Determination of the relation between the intensity of light and the temperature.

Measurement of radiation in absolute measure.

Determination of the distribution of energy in the spectrum of black bodies.

Determination of the distribution of energy in the spectrum of polished platinum and other substances ; also their reflective power.

SECOND (TECHNICAL) DIVISION.

I. *Work of Mechanical Precision.*—Investigation of the errors of length and of the division of 300 scales, tubes, etc.

Coefficient of expansion of 18 bars, tubes and wires.

Verification of 86 tuning forks for international pitch.

Construction of a new transverse comparator.

Study of the variations of angular velocity of rotating bodies.

II. *Electrical Work.*—Calibration of direct current apparatus, 183 pieces.

Calibration of alternating current apparatus, 58 pieces.

Examination of other electrical apparatus, 76 articles.

Examination of accumulators, primary elements and switches, 37 articles.

Examination of insulating and conducting materials and carbons, 23 articles.

Installation of storage cells for a current of 10,000 amperes.

Installation of small storage cells for an electric pressure of 20,000 volts.

Installation of alternating current instruments for measuring potential difference up to 500 volts and current up to 100 amperes.

Examination of 29 samples of alloys for specific resistance and temperature coefficient.

Examination of 126 samples of insulating materials with an electric pressure up to 800 volts.

Verification of single resistances, 123 samples.

Calibration of 33 resistance boxes, compensation apparatus, etc., containing 1,153 resistances.

Comparison and verification of 133 standard cells—111 Clark and 22 Weston elements.

Determination of the ratio Clark 15° C. to cadmium 20° C., and Clark 0° C. to cadmium 20° C. with a large number of standard cells.

Examination of 21 samples of dry and storage cells.

Calibration of 25 galvanometers to measure high and low temperatures with thermal elements.

Magnetic examination of 25 samples of iron and steel.

Investigation of the difference between the continuous and the discontinuous magnetization of steel.

Investigation of the influence of repeated heating on the magnetic hardness of iron.

III. *Work Relating to Heat and Measurement of Pressure.*—Calibration of 18,777 thermometers.

Examination of 4 safety appliances and benzine lamps.

Calibration of 317 thermal elements.

Verification of 9 manometers and 22 barometers

Testing of 190 samples of apparatus for petroleum investigations.

Testing of 3,210 samples of safety rings and plugs.

Testing of 32 samples of indicator springs.

IV. *Work in Light.*—Testing of 119 Hefner lamps for photometric purposes.

Testing of 189 incandescent lamps.

Testing of 143 gas and other lamps and adjunct appliances.

Investigation of the relation between the temperature of sugar solutions and their rotary power on polarized light.

Investigation of quartz plates for the examination of sugars.

Determination of 100 points in the normal Ventzke scale for sodium light.

Especially careful collection of sugars from Germany, Austria, France, Russia and North America for the investigation of specific rotatory power.

V. *Work in Chemistry.*—Continuation of the study of the solubility of important salts.

Electrolysis of platinic chloride and the migration of the ions.

The quantitative determination of metallic platinum.

Investigation of liquids for use in thermometers to measure low temperatures.

In addition to the above work attention is drawn to the fact that there are two institutions for the calibration and certification of thermometers under the control of the Reichsanstalt, one at Ilmenau and the other at Gehlberg. During the last ten years the institution at Ilmenau has tested in round numbers 350,000 thermometers.

The number of persons employed in the Reichsanstalt the past year was 87.

V. A LESSON FOR US.

If Germany has found it to her scientific and industrial advantage to maintain the Reichsanstalt, and is proud of what it accomplishes; and if Great Britain is so impressed with the success of the institution that she has decided to imitate it, it is surely the part of wisdom for the United States to move in the same direction. It is therefore very gratifying that at the suggestion of Secretary Gage a bill was introduced in the last Congress to establish a National Standardizing Bureau, and that the Committee on Coinage, Weights and Measures reported unanimously and strongly in favor of its passage. So great is the importance of this movement from the point of view of science, of national pride and of the higher interests of industrial pursuits, that the effort so happily begun to secure suitable legislation should be repeated with redoubled force and enthusiasm. Some of the reasons for making this effort one does not need to go far to seek.

In the first place the scientific interests to be served are certainly as great as in any other country in the world. Science is cultivated here with increasing assiduity and success. We are no longer content to follow in the footsteps of European savants and modestly repeat their investigations. Original work of a high order is now done in many American universities; but the difficulties under which university instructors prosecute research are even greater here than in Germany, and we are still compelled to go to Europe for most of our standards. As a result, inventions of an almost purely scientific character originating here have been carried to perfection in the Reichsanstalt, and Germany gets the larger part of the credit. I need only instance the Weston standard cell, which has been so fully investigated at the Reichsanstalt, and the alloy 'manganin,' which the same institution employs for its standard resistances after a searching inquiry into its properties. Both of these are the invention of Mr. Edward Weston, one of the Past-Presidents of this Institute. So long as there is no authoritative bureau in the United States under Federal control, and presided over by men commanding respect and confidence, we must continue 'to utilize the far superior standardizing facilities of other governments.' It is true that science knows no nationality, but the scientific workers of any nation can serve their own country better if they are not compelled to obtain their standards and their best instruments from distant parts of the globe. America has the cultivation in physical science, the ability on the part of her investigators and the inventive faculty to do work in a national institution that we shall not be ashamed to place by the side of Germany's best products. The establishment of a national institution for physical and technical purposes

can not fail to foster a vigorous and healthy growth in science, to which we already owe so much of our national prosperity and renown.

In the second place Congress should be stimulated to take action because of national pride. It is not creditable for a capable and self-reliant nation to continue to depend on foreign countries for its standards of measurement, for the certification of its instruments and for the calibration of its normal apparatus for precise work. Different departments of our Government and offices under its control must at present appeal to foreign bureaus for the certification of their standards and instruments of precision. The first day the writer spent at the Reichsanstalt he was consulted with reference to an extended correspondence between the Director of the technical division and the officials of the Brooklyn Navy Yard relative to the calibration of a large number of incandescent electric lamps for use in our Navy department. The spectacle of a Government bureau going to a foreign imperial institution for standards in an industry whose home is in the United States is a humiliating one. Yet the proceeding was entirely proper and justifiable because there is in this country no standardizing bureau for the purpose desired. Are the representatives of the American people willing to have this state of affairs continue?

Again, the higher interests of the industrial utilization of scientific knowledge require the establishment in Washington of an institution similar to the Reichsanstalt, and in no degree inferior to it. We are an inventive people and may justly claim renown in the prompt and efficient utilization of the discoveries in physical science. It is highly improbable that a practical limit has already been reached in the field of applied physics. We are not estopped from making further discoveries. Still, it may be affirmed with confidence that the most important and promising work to be done, except in the rare instances in which genius makes a brilliant discovery, will consist in the more perfect adaptation of known physical laws to the production of useful results. It is precisely this field which has not been extensively cultivated as yet in the United States. We have explored the surface and presumably gathered the largest nuggets and the most brilliant gems. To increase the output we must now delve deeper and scrutinize more closely. To drop the metaphor, what will be required for future preeminence is the more intensive and exhaustive study of the scientific conditions in the industrial utilization of physical laws. This study will require the best talent of our technical schools, aided and supported by an authoritative national institution, itself far removed from patents and commercial gains, but jealous of our national renown and eager to cooperate with manufacturers for the sake of national prosperity.

Germany is rapidly moving toward industrial supremacy in Europe. One of the most potent factors in this notable advance is the perfected alliance between science and commerce existing in Germany. Science has come to be regarded there as a commercial factor. If England is losing her supremacy in manufactures and in commerce, as many claim, it is because of English conservatism and the failure to utilize to the fullest extent the lessons taught by science; while Germany, once the country of dreamers and theorists, has now become eminently practical. Science there no longer seeks court and cloister, but is in open alliance with commerce and industry. This is substantially the view taken by Sir Charles Oppenheimer, British Consul-General at Frankfurt, in a recent review of the status and prospects of the German Empire.

The Reichsanstalt is the top stone of Germany's scientific edifice. It has also contributed much to her industrial renown.

It is necessary to cite only her manufactures involving high temperatures, such as the porcelain industry, to appreciate the help afforded by the Reichsanstalt. The methods and instruments elaborated there for the exact measurement of high temperatures constitute a splendid contribution toward industrial supremacy in those lines. The German government sees with great clearness that the Reichsanstalt justifies the expenditure made for its maintenance, not by the fees received for certifications and calibrations, but by the support it gives to the higher industries requiring the application of the greatest intelligence. In this connection it should be thankfully acknowledged that the services of this imperial establishment are placed at the disposal of foreign institutions of learning with the most generous liberality. The charges for calibration are only about one-fourth the expense incurred in making them, but the support thus given to German makers of instruments of precision, by increasing their foreign orders, is deemed a sufficient return for the services rendered.

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PLANT GEOGRAPHY OF NORTH AMERICA.

I.

THE PHYSIOGRAPHIC ECOLOGY OF NORTHERN MICHIGAN.

I. *The Physiographic Standpoint in Ecology.*—Warming's classification of plant formations, doubtless the best we have, is inadequate to explain many of the facts that are brought out in field study. While water is certainly the most important single ecological factor, it cannot be made the only standard for classification; the difference between the flora of drained and undrained swamps is not a question of water content, but probably of drainage; a heath and a moor have similar ecological adaptations, but are very diverse as to water content. A classification to be correct must also be dynamic and must present the flora of a district from the standpoint of its past and future, thus dealing with genetic relationships. A classification which runs parallel with the normal physiographic changes in a region meets all these needs and presents the flora as a unit, taking account of all the interrelations. The various ecological groups or plant formations are presented in a historical sequence, ending in a normal climax or culminating type, corresponding to the base level of physiography.

II. *Application of the Physiographic Standpoint to Northern Michigan.*—A. Progressive Development of Plant Formations. The vast majority of natural formations are developing toward the climax type, which for Northern Michigan is a mixed forest in which the hemlock, beech and sugar maple dominate. At the outset the conditions may be xerophytic or hydrophytic (using these terms in the original sense as referring to the water content of the soil).

1. Xerophytic to Mesophytic. In a young region, xerophytic formations are found commonly on hills and along exposed shores. The development on the hills is widely variant; perhaps the climax condition is first reached on clay hills, because of the ease with which water is held and humus formed. Sand hills reach mesophytic conditions relatively late, because they possess opposite physical characters. Rock hills commonly have a slow development because disintegration and soil formation are first necessary; a lichen vegetation first appears, then a crevice vegetation, finally other stages, closing with the mesophytic forest. Rock hills of course vary greatly among themselves, the development being almost inconceivably slower on granite or quartzite than on limestone or shale. Xerophytic shores are much more uniform, having first an annual, then a perennial vegetation, and finally the several forest